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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LX. No. 10. SUPPLEMENTARY NUMBER.

INVITATION OF LADIES TO THE ORDINARY MEETINGS OF THE SOCIETY.

The attention of Fellows is called to the fact that ladies are only admitted to the Ordinary Meetings of the Society by special invitation of the President, sanctioned by the Council. The invitations are issued at the commencement of each Session.

THE LIBRARY.

The attention of Fellows is called to the following resolution of the Council at their meeting of 1896 November 13 :—

"All books must be actually returned to the Library on or before the second Friday in November in each year, and not taken out again till the following Friday without special permission."

APPENDIX TO VOL. LX.

The preliminary reports of the Observations of the Total Solar Eclipse of 1900 May 28 will shortly be issued as an Appendix to the present volume of Monthly Notices, simultaneously with their appearance in the Proceedings of the Royal Society (*vide M.N.* Vol. LVIII., p. 414).

The Index to the whole volume will be circulated with this Appendix.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LX. SUPPLEMENTARY NUMBER, 1900. NO. 10

A Possible Explanation of the Sun-spot Period.

By Ernest W. Brown, D.Sc., F.R.S.

This paper is an attempt to obtain a gravitational cause for the Sun-spot period on somewhat different lines from those which have hitherto been followed.*

The possibility that the period is in some way connected with the positions of the planets has been frequently suggested. Carrington, in his well known work, has given a comparison of the curve formed from the Sun-spot numbers with one having the same period as that of *Jupiter* round the Sun. Balfour Stewart (*Trans. R. S. Edin.*, vol. xxiii.) examined the influence of *Jupiter* and the inner planets. Birkeland (*Vidensk. Skrifter*, 1899, Christiania) has done a similar piece of work on a much more extended scale. These investigations all appear to have produced a negative result as far as the main period is concerned, the chief reason being that the only long-period planet considered, *i.e. Jupiter*, has a period of 11·86 years, so that the examination ultimately reduces to an attempt to make the *Jupiter* curve agree with the Sun-spot curve. It will be seen below that the main difference of the method followed here from that of previous investigators, is the inclusion of an action due to *Saturn* combined with that of *Jupiter*, with possible minor effects due to the inner planets, instead of considering *Jupiter* and the inner planets only. If we compound two periodic curves of nearly equal amplitudes and

* Part of the paper has been re-written since it was first presented to the Society, owing to the valuable criticisms of the referees. My attention was also called by them to the memoir of M. Birkeland, which has appeared during the present year.

periods not very different, an *apparent* period may result different from the component periods when the series does not extend over a very great number of maxima.

If we examine the tide-raising forces on the Sun due to the planets, we obtain the following relative numbers :—

By *Mercury*	8·6	By *Jupiter*	2·24
„ *Venus*	2·06	„ *Saturn*	·11
„ The Earth	1·00	„ *Uranus*	·002
„ *Mars*	·03	„ *Neptune*	·0006

The mean values of the distances of the planets are used, taking the mean distance and mass of the Earth as units. The mass of *Mercury* is assumed to be $\frac{1}{20}$ that of the Earth ; any probable change in this value will not affect the argument of this paper.

It is at once seen that the inner planets, with the exception of *Mars*, all produce considerable relative effects, but as their periods are very short, it will be assumed that they can be neglected in the search for long-period effects. As *Uranus* and *Neptune* can hardly be supposed, from the numbers given above, to have any influence, *Jupiter* and *Saturn* alone remain.

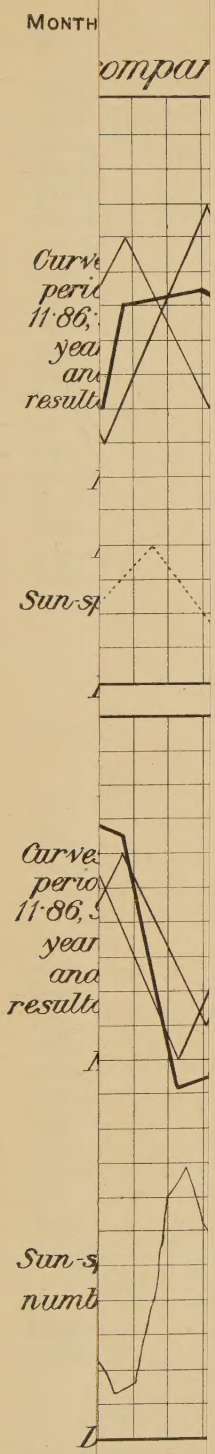
Now *Jupiter* alone, if we neglect the eccentricity of its orbit, cannot in general produce any long-period term, for the period of rotation of the Sun is about twenty-five days, and the wave produced by *Jupiter* travels round the Sun, relatively to the Sun's surface, in very nearly the same period. The eccentricity of the orbit of *Jupiter* is however about $\frac{1}{20}$, and the tide-raising force, 2·24, due to *Jupiter*, will vary by $\pm$·33 as the planet moves in its orbit. This may be considered as a wave superposed on the main *Jupiter* wave, and its period will be that of *Jupiter*, since the motion of the perihelion can be neglected.

Again, *Saturn*, in its motion round the Sun, raises a wave with a force of magnitude ·11. Whenever this wave crosses the main *Jupiter* wave, the latter will have its height increased, and there will be a corresponding diminution when the waves are in quadrature with one another. The period of the wave relative to the main *Jupiter* wave will be that of *Saturn* relative to *Jupiter* round the Sun, that is, 19·86 years. But as a tide-raising force produces equal waves on opposite sides of the Sun, the intervals between coincidences will be just half of this, that is 9·93 years.

Hence the main *Jupiter* wave is periodically altered by two causes :—

	Period.	Mag. of force.
By Jupiter's eccentricity	11·86 years	·33
By the motion of Saturn	9·93 „	·11

The two forces are in the ratio 3 : 1, but these numbers cannot contribute anything to the argument further than that they are of the same order of magnitude, even if that is necessary. For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the question under consideration is not the periodic change in the wave height, but a phenomenon here supposed to be due to this change : namely, increase of activity on the Sun's surface due to the relative positions of the waves which in reality form long-period "spring" tides. The periods are the only quantities which admit of more or less exact numerical calculation.

Now, the period of activity of the solar surface has generally been estimated at 11·1 years, and as the number of maxima from which it is deduced is not very large, it might easily have been arrived at even if the actual curves be really compounded from two of not very different amplitudes. It must be remembered also that the period is only an average one ; the distances between the various maxima actually range from about 8 to 18 years, so that even if a principal cause with a period of 11·1 years had been found, the deviations would have been considerable.

In the course of the 150 years during which numerical estimates of the activity are available, there is some evidence of a much longer periodic change which appears to run from one maximum to the next in about sixty years. This can be shown to be a direct consequence of the two periods. For

$$5 \times 11{\cdot}86 = 59{\cdot}3,$$
$$6 \times 9{\cdot}93 = 59{\cdot}6,$$

the exact period between two coincidences of phase being

$$1 \div \left(\frac{1}{9{\cdot}93} - \frac{1}{11{\cdot}86}\right) = 61 \text{ years.}$$

Thus every 61 years the two waves are in approximately the same positions relatively to the main *Jupiter* wave, and a corresponding change in the Sun-spot cycle may be expected.

A curve (plate 20) has been drawn, showing the effect of the combination of two periodic terms of periods, 11·86 and 9·93 years respectively. In order to simplify the drawing as much as possible, only the maxima and minima of these were plotted, and they were then joined by (thin) straight lines. The minima were placed at equal distances from the maxima, although a more exact agreement might perhaps have been obtained by making the distance from maximum to minimum longer than that from minimum to maximum. The amplitudes must, from the nature of the case, be somewhat arbitrary, judging from the numerical analysis given later on. They were taken in the ratio of 7 : 5, the larger amplitude being used for the *Jupiter* period. The maxima are placed below and the minima above. The heavy line shows the effect of compounding the two curves.

The lower curve represents Wolf's Sun-spot numbers. In the period before 1750—the dotted portion—the magnitudes are not known ; the maxima have therefore been drawn with equal ordinates. For the period since 1750, the Sun-spot curves are

plotted from the annual means given by Wolf.* Thus a period of about 290 years is available for comparison.

In the period before 1750, represented on the upper part of the plate, one must regard Wolf's results with considerable doubt. No connected series of observations were then available. A maximum was sometimes inferred from the mention of a big spot on the Sun easily visible to the naked eye ; such a spot has occurred during the minimum now in progress, and therefore one can hardly regard the deduction of a maximum from a big spot as very trustworthy. In fact Wolfer, in rediscussing Wolf's results, gets in one part two maxima and one minimum where Wolf had found only one maximum. Again, it is not easy to decide on what principle (*e.g.* by the number of spots visible in a given time, or by the spotted area) the Sun-spot curves should be formed. The hump which is visible in several cases on the descending slope may possibly come out as the real maximum by another method of reckoning. In fact, the curve gives an appearance of definiteness which disappears when the observations are more closely examined. A reference to the plate attached to Mr. Ellis's paper in the *Monthly Notices* for last December will illustrate this last point ; the Sun-spot curves are there drawn on a larger scale from the monthly instead of the annual means.

On comparing the theoretical and observed curves, it will be seen—

(*a*) That the maxima agree on the whole fairly well, and better in the later than in the earlier times.

(*b*) That from 1750–1898 there are three minima and two maxima of the 61-year period which agree fairly well with those of the Sun-spot curve.

(*c*) That at all the maxima of the 61-year period there is an almost exact coincidence of the theoretical and observed maxima.

(*d*) That the deviations from coincidence of the maxima generally occur where they might be expected to occur—namely, round the minima of the 61-year period. This is, in particular, the case before 1750.

(*e*) That the principal deviations are the maxima of dates 1615, 1675, 1894 ; the deviations of dates 1626, 1685, 1750, 1761 being near the minima of the 61-year period. The first two exceptions are probably due to errors in assigning the dates to these maxima of the Sun-spot curves. Wolf says that there is a probable error of about two years in the date of each maximum before 1750 ; an error of four years in each of these cases is not improbable. The supposition of error is strengthened by the fact that the slope from maximum to minimum is greater

* Wolf's results have been summarised by A. Wolfer in the *Meteorologische Zeitschrift* for June 1892. The results up to 1891, used here, have been obtained from this paper ; for the period 1891–8 the numbers were extracted from Wolfer's annual reports.

than that from minimum to maximum—contrary to what happens with the great majority of the 11·1-year periods.

The deviation of the maximum apparently occurring about 1894 is not so easily explained away, as it is in a period when doubt cannot be cast on the observations. In fact, it appears to coincide more nearly with the theoretical minimum than with the maximum. A general shift back of the theoretical curve will not improve matters. The explanation would probably be that there are other causes tending to displace the position of the actual maximum. The prolonged minimum now in progress seems to confirm this. If the theory developed here is correct, the actual minimum should not be reached until 1901 or 1902, if it is attained as early. The next maximum should be a period of great activity, as it will fall on a maximum of the 61-year period, and it should be attained about 1908. The time-distance from the previous maximum would be about 14 years—an event which is not unusual, as a reference to the plate will show.

The rise of the curve about 1870 is seen by a reference to the monthly means to be due to a very large disturbance lasting a comparatively short time.

(*f*) That the maxima of disturbance do not coincide with the positions of conjunction or opposition of *Saturn* and *Jupiter*. These planets were in conjunction and *Jupiter* was at aphelion in 1827, a date about ten years from the minimum of the 61-year period.

A closer agreement between the two curves can hardly be expected, in view of the many arbitrary quantities which enter into their formation. In addition, the actions of *Mercury*, *Venus*, and the Earth may produce effects comparable with those produced by *Jupiter* and *Saturn*; they might well cause considerable deviations of the maxima at any one period, and their effects would only be eliminated by an analysis of the observations extending over a considerable period of time. It therefore seems advisable to examine the numbers, and to see what evidence of the existence of the periods the observations afford.

For this purpose the mean annual values of the Sun-spot numbers given by Wolf were used. The period 1761–1880 is the longest complete cycle which is available; this includes 12 maxima of the 9·93-year period, and 10 of the 11·86-year period. Arranging these in groups of 10, for the former period we obtain the following mean values :—

1	2	3	4	5	6	7	8	9	10
57	47	34	30	27	38	54	65	67	64

The numbers 1, 2 . . . are the parts of a period, and the mean under each is derived from twelve annual means, each of the latter being derived from the twelve monthly numbers

given by Wolf. Although the period is rather less than ten years, the difference is not sufficient to have any material effect in the course of 120 years. These ten means are plotted in fig. 1, the numbers at the side corresponding to Wolf's Sun-spot numbers, and those below corresponding to the above ten parts of a period.

9·93-year Period.

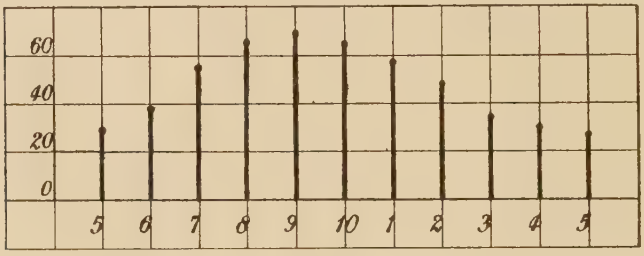

FIG. 1.

Next, to test the 11·86-year period, the same numbers were arranged in groups of twelve. Owing to the fact that 120 years is rather more than ten periods, to save trouble the device adopted in the reduction of tidal observations was used —an extra number, the mean of those immediately preceding and following, was inserted in the middle of the series, which thus extends over 119 years. The resulting twelve means, each formed from ten annual means, are as follows :—

1	2	3	4	5	6	7	8	9	10	11	12
25	33	47	57	73	72	65	60	55	43	29	20

As before, the numbers 1, 2 . . . 12 are parts of a period ; the values have been plotted in fig. 2.

11·86-year Period.

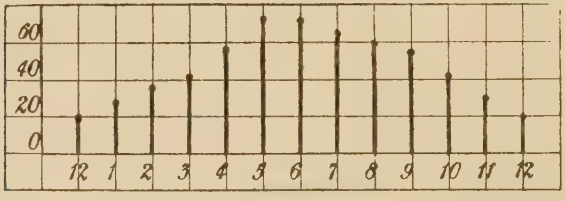

FIG. 2.

In each case the differences from the value of the mean, 48, seem to justify an assertion as to the existence of the periods.

An attempt was next made to see if any of the other periods were to be found in the Sun-spot numbers. The following are those which seemed most likely to be shown on account of the magnitudes of the forces :—

Mercury, effect of eccentricity, ·24085 year.

M—V, ·19795 year,	V—J, ·32242 year,
M—E, ·15863 „	E—J, ·54603 „
M—J, ·12292 „	V—E, ·79936 „

where M, V, E, J, denote *Mercury*, *Venus*, the Earth, and *Jupiter*, respectively, and M—V, M—E, . . . , the halves of their relative periods. The halves of all the periods, except that due to the eccentricity of *Mercury*, must be used owing to the fact that two equal waves are raised on opposite sides of the Sun, and we are only concerned here with the coincidences of these waves. All of these periods are short, and it is very doubtful whether the observations can be taken with sufficient accuracy to test any of them. However, an attempt was made with the longest, V—E, which has a period of almost exactly four-fifths of a year. In the course of sixty years the deviation from an exact period of four-fifths would be less than a fortnight. I therefore took Wolf's monthly means from 1831–1890, which is almost exactly a long-period cycle, and arranged them in 48 columns corresponding to the 48 months in a four-year period. These 48 means, each formed from 15 numbers, should give 5 maxima and 5 minima if the action of V—E is to be shown. The means are given in the following table :—

Month 1	2	3	4	5	6	7	8	9	10	11	12
Year.											
1	42·3	46·5	50·4	47·4	44·3	41·9	43·3	54·7	52·7	57·6	53·2	47·9
2	54·5	57·3	55·6	52·3	51·7	52·2	53·2	51·7	50·2	55·4	52·2	59·4
3	54·9	58·1	51·5	51·7	51·2	54·7	51·3	49·5	46·0	43·9	43·1	48·1
4	43·8	46·9	53·7	49·2	50·9	45·3	44·1	43·7	51·3	46·8	45·3	40·9

Plotting these as before, we obtain the curve in fig. 3, where the numbers 18, 22 . . . show the ordinates which correspond to year 2, month 6; year 2, month 10, etc., in the above table.

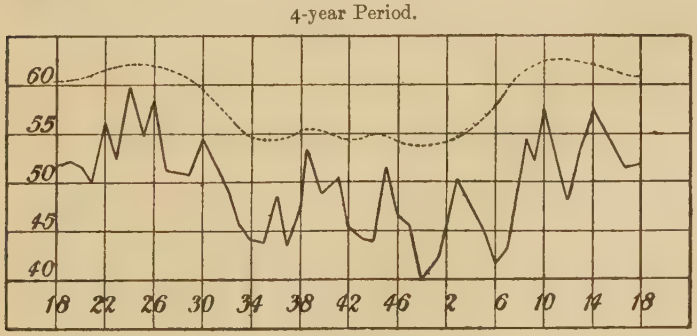

Fig. 3.

The four-year period which appears to result from this curve is illusory. If a succession of 12-year periods be plotted in groups of four years, the maxima will all fall in one place; thus the apparent four year period is due to the 11·86-year period. Similarly, the apparent approximate symmetry about the centre of the curve in fig. 4, as shown by the dotted line, is due to the 9·93-year period; an even number of such periods arranged in groups of 4 years will give an approximately symmetrical curve.

As we are searching for a $\frac{4}{5}$-year period, the numbers in the table should contain five periods. Dividing each period into nine equal parts and estimating their magnitudes from fig. 4,* we obtain the following series of means for the nine parts of the period :—

1	2	3	4	5	6	7	8	9
50·7	49·9	51·0	50·0	48·5	49·0	49·6	49·4	49·9

which are plotted in fig. 4.

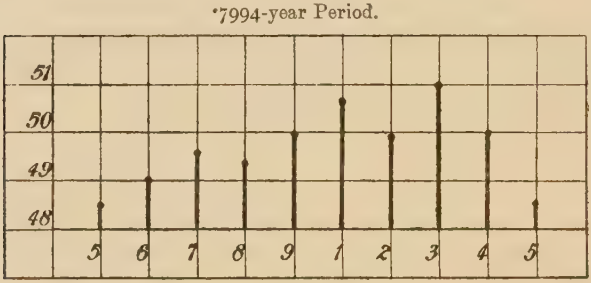

Fig. 4.

Although each of the nine means arises from about 80 monthly means, and although their general change seems to afford some evidence of the required period, the differences from their mean value are too small to give more than a doubtful indication of the existence of the period.

1900 Aug. 4.

* They were actually estimated from a large-scale figure.

Note on the Formulæ for Star Corrections. By P. H. Cowell, M.A.

The following method of obtaining the formulæ used in star corrections appears to me simpler than that usually given in text books.

(i.) Precession and Nutation.

Some rotation will bring the pole and equinox of date into coincidence with the mean pole and equinox for the beginning of the year. Let this rotation be resolved into components :

D round the first point of *Aries* ;
C round the pole of the prime celestial meridian ;
f round the pole of the equator.

D, C, f are therefore day-numbers independent of the particular star.

Then for a particular star, whose R.A. and declination are α and δ, the rotation may be farther resolved into

C sin α + D cos α about the projection of the direction of the star upon the equator ;
C cos α — D sin α about the pole of the meridian through the star ;
f about the pole of the equator.

The geometrical effects of these last-named rotations are

(C sin α + D cos α) $\frac{1}{15}$ tan δ	in R.A.
C cos α — D sin α	in Decl.
f	in R.A.

(ii.) Aberration.

The effect of aberration is the same as that of a displacement of the observer. This displacement may be resolved into components :

B towards the first point of *Aries* ;
A towards the pole of the prime celestial meridian ;
i towards the pole of the equator.

B, A, i are therefore day-numbers independent of the particular star.

Then for a particular star the displacement may be further resolved into

A sin α + B cos α along the projection of the direction of the star upon the equator ;
A cos α — B sin α at right angles to the meridian of the star ;
i towards the pole of the equator.

The geometrical effects of these displacements are

$$\begin{array}{ll} -(\mathrm{A}\sin\alpha + \mathrm{B}\cos\alpha)\sin\delta & \text{in declination ;} \\ (\mathrm{A}\cos\alpha - \mathrm{B}\sin\alpha)\,\tfrac{1}{15}\sec\delta & \text{in R.A. ;} \\ i\ \cos\delta & \text{in declination.} \end{array}$$

Combining the two results, and reversing the signs of some of the day-numbers, we have the well-known formulæ :

Apparent R.A.—Mean R.A.

$$\begin{aligned} &= \mathrm{A}\ \tfrac{1}{15}\cos\alpha\sec\delta + \mathrm{B}\ \tfrac{1}{15}\sin\alpha\sec\delta \\ &+ \mathrm{C}\ \tfrac{1}{15}\sin\alpha\tan\delta + \mathrm{D}\ \tfrac{1}{15}\cos\alpha\tan\delta + f. \end{aligned}$$

Apparent Declination—Mean Declination.

$$\begin{aligned} &= -\mathrm{A}\sin\alpha\sin\delta + \mathrm{B}\cos\alpha\sin\delta \\ &\quad + \mathrm{C}\cos\alpha \qquad - \mathrm{D}\sin\alpha + i\cos\delta \end{aligned}$$

where it should be observed that C has a slightly different meaning to that assigned to it in the *Nautical Almanac* (see Turner's Star Correction Tables).

This method of treatment assigns geometrical meanings to the day-numbers, and from their geometrical meaning some of their numerical properties are easily recalled ; for instance :

D is the nutation in obliquity, and its principal term has a nineteen-year period ;

C, f are components of the precession and nutation in longitude. As these are together equivalent to a rotation about the pole of the ecliptic (except for the minute planetary precession), it follows that $\mathrm{C}=f\tan\epsilon$, nearly, when ϵ is the obliquity of the ecliptic, or $\mathrm{C}=\frac{2}{5}f$, nearly.

Moreover C, f alone of the day-numbers change suddenly at the turn of the year, and contain a term proportional to the fraction of the year. The principal parts of the remainders of C and f, and the principal part of D, are of nineteen years' period, and depend, as is well known, on the fact that the lunar precession is equivalent to a rotation round the pole of the Moon's orbit, which revolves in nineteen years round the pole of the ecliptic.

A, B, i are components of a vector the extremity of which describes the hodograph of the Earth's orbit. This hodograph is a circle ; the vector represented by A, B, f, is not drawn from the origin but from the centre of the circle. The Earth's velocity is the resultant of two components, one of which is a constant, and produces an aberration whose value for stars 90° distant from its apex is $\frac{1}{3}''$, while the other component is constant in magnitude and at right angles to the Earth's radius vector. It is perhaps not familiar to everyone that, when an apparent place is corrected for aberration by the ordinary formulæ, the mean place is not that in which the star would appear were the Earth at

rest, or the velocity of light infinite, but it remains affected by the aberration due to a velocity parallel to the minor axis of the Earth's orbit.

A, *i* have a resultant in the plane of the ecliptic, and therefore $i = \frac{2}{5}$ A, nearly ; also A, *i* vanish at the solstices, while B vanishes at the equinoxes.

In connection with the uncorrected portion of the aberration, it may be further remarked that a planet is completely corrected for aberration by antedating the observation, so that there is a discordance of $\frac{1}{5}''$ in the method of treating the two classes of bodies.

Partial Eclipse of the Sun, 1900 *May* 28, *observed at Col. Cooper's Observatory, Markree.* By F. W. Henkel, B.A.

The weather being very fine here, the progress of the eclipse was watched under favourable circumstances.

The maximum obscuration was at about 3.45 P.M. G.M.T., and magnitude of eclipse ·7.

The last contact took place at $4^h\ 49^m\ 25^s$ G.M.T. There was a slight falling off of light observable during the time of greatest obscuration.

The sunshine record for this date gives a graphic picture of the eclipse (or rather the uneclipsed portion of the Sun), shown by the narrowing down of the trace and its subsequent widening again during the progress of the phenomenon. The Merz "Comet Seeker," with dark glasses, was the instrument used to watch the eclipse.

Discovery and Observations of Comet Brooks (*b* 1900). By W. R. Brooks, M.A., D.Sc.

While engaged in sweeping the eastern heavens with the $10\frac{1}{4}$-inch refractor on the early morning of July 23, I discovered a new, bright, telescopic comet in *Aries*. Its position was as follows : July 23, 13^h, Eastern standard time ; R.A., $2^h\ 43^m\ 40^s$; declination north, 12° 30′. The motion was rapid, about 3° daily, and almost due north. The comet had a bright stellar nucleus and a tail. It was really a very beautiful telescopic object, resembling a great naked eye comet in miniature.

In drawing fig. 1 I show its normal appearance shortly after discovery, which was maintained with very slight variation until the full moon interfered with the almost continuous obser-

vations at this observatory. There was noted, however, one remarkable exception. On July 26, at $13^h\ 25^m$, two branching wisps or streamers were seen issuing from either side of the coma,

FIG. 1.

FIG. 2.

and making an angle of about thirty degrees with the principal tail. The northern streamer was the more prominent of the two.

Two hours later, or at $15^h\ 30^m$, on the same morning I could not detect the branching tails. The approximate position of the comet at this time was R.A. $2^h\ 46^m\ 35^s + 21°\ 16'$. On the following morning these streamers could not be seen, neither have I been able to detect them upon any subsequent occasion. The nucleus of the comet, which was remarkably sharp and well-defined, has always appeared elongated or pear-shaped. It has much resembled an unequal double star with the discs in contact. On two occasions it seemed possible to separate the nucleus with a sufficiently high power, but I was unable to do this with a magnifying power of 500 diameters.

On August 1 the comet was seen in the same low-power field with *Algol*.

My latest observation of the comet was last evening, August 8, when it was seen without difficulty in the presence of a nearly full Moon, and in R.A. $2^h\ 55^m\ 35^s + 59°\ 7'$. The comet is, therefore, now circumpolar, in *Camelopardalis*, and promises to be visible in moderate apertures for some time to come.

Smith Observatory, Geneva, N.Y., U.S.A.:
1900 *August* 9.

P.S.—Since the foregoing was written, it is learned from the *Ast. Nach.*, No. 3653, that the comet was independently dis-

covered by Borrelly the same morning. It is an interesting fact that although the difference in longitude of the two stations is about five hours, the Harvard cablegram announcing my discovery reached Kiel two hours before Borrelly's.

Nebulæ Discovered at the Chamberlin Observatory, University Park, Colorado. By Herbert A. Howe.

(*Communicated by the Secretaries.*)

During the twelve months ending 1900 June 30, the following nebulæ, supposed to be new, have been noted. The positions of all except one have been micrometrically measured, and are given for 1900·0. All owe their discovery to their proximity to known nebulæ, the places of which were being measured. In the "Descriptions" and "Notes" numbers enclosed in brackets refer to the Index Catalogue; others are the current ones of the N.G.C.

No.	Date.	R.A. h m s	Dec. ° ′	Descriptions
	1899.			
1	Nov. 6	0 30 28	− 3 25·7	eF, vS, in field with 161.
	1900.			
2	Jan. 1	1 18 57	− 2 10 6	eF, vS, possibly only a faint star.
3	Jan. 19	1 19 46	− 2 8·3	eF, eS; 530 is n.p.
4	Jan. 1	1 47 8	−17 16·9	eF, eS.
5	Jan. 1	1 48 11	−17 9·7	eF, eS.
	1899.			
6	Nov. 24	1 52 4	−17 1·7	F, eS.
	1900.			
7	Jan. 30	2 38 58	−16 7·7	vS, vF, mbM; near 1081.
8	Jan. 23	2 43 20	−14 24·6	eF, vS; near 1103.
9	Jan. 31	2 50 11	−16 3·5	vF, eS; almost stellar.
10	Jan. 30	3 1 38	−10 6·9	eF, S.
11	Jan. 22	3 4 1	−23 26·3	vF, L; near 1230.
12	Jan. 24	3 5 57	−11 10·6	eF, vS; near 1238.
13	Jan. 19	3 34 27	−15 49·6	eF, eS, v diffic.; near 1405.
14	Jan. 20	4 9 57	−13 25·5	eF, eS, almost stellar; near 1538.
15	Jan. 20	4 10 17	−13 26·5	eF, eS, diffic.; near 1538.
16	Jan. 31	4 27 25 ±	− 5 58 ±	eF, vS; f 1594, 90^s ±, 3′n.
17	Jan. 22	5 48 12	−17 48·5	eF, pS; near (438).
18	Apr. 19	10 58 56	−19 33·3	vF, vS.
19	June 29	13 1 16	+54 13·2	vF, vS.
20	June 21	13 43 24	−29 47·8	F, eS, bM.
	1899.			
21	Sept. 11	18 12 41	+61 7·6	eF, eS, v diffic.; near 6617.
22	Nov. 25	23 19 47	+13 26·8	eF, eS; near 7651.
23	Nov. 27	23 33 27	+26 25·9	eF, eS; near 7720.
24	Nov. 27	23 33 38	+26 27·4	eF, eS; near 7720.

Notes.

No. 1 is attended by a star of mag. 14, a trifle south, and by another, which follows the nebula closely.

No. 2 is accompanied by a star of mag. 13, a trifle south preceding. The nebula is about 3′ from 530, which is identical with (106), the position of 530 in the N.G.C. being slightly erroneous. According to my measures, the position of 530 is $1^h\ 19^m\ 36^s - 2°\ 6'{\cdot}5$; this agrees with Bigourdan's place for (106). No. 4 should perhaps be reckoned as identical with 690, though the N.G.C. place of the latter is $1^h\ 44^m\ 31^s - 17°\ 14'{\cdot}0$ when reduced to 1900·0. However, Leavenworth's declinations are not apt to be so erroneous as would be the case if No. 4 were identical with 690. No. 6 is a star of mag. 11, with very slight outlying nebulosity.

No. 7 is equivalent in brightness to a star of mag. 13.

No. 10 is accompanied by a star of mag. 9 which follows eight seconds at the same declination.

No. 19 is near (847); 4973 and 4974, according to the N.G.C., follow No. 19 less than a minute of time; but their relative positions are not the same as those of (847) and No. 19. I looked for them on one night, when the seeing was poor, and could not be sure of them.

No. 22 precedes a star of mag. 9·5 thirteen seconds, 0′·2 north.

No. 24 looks like a star of mag. 13, blurred atmospherically. Other faint nebulæ are suspected in its vicinity.

No. 15 of the list in *M.N.* lviii. 9, has now been measured micrometrically, and its position is $12^h\ 45^m\ 43^s - 13°\ 57'{\cdot}1$.

A nebula is suspected 5′ south of 4862. Two or three very faint nebulæ are suspected near 5664.

Ephemeris of Eros. By Frank Robbins.

In the *Astronomical Journal* (Vol. xix. No. 19, 451, 1898, December 12, page 155), Dr. S. C. Chandler, of Cambridge, U.S.A., has given the orbital elements upon which is founded the ephemeris now offered to the Royal Astronomical Society.

Dr. Chandler's elements were derived from the discussion of 142 observations, both visual and photographic, made at Berlin, Mount Hamilton, Washington, Harvard, and elsewhere, by the discoverer, De Witt, and by various observers, including Hussey, Frisby, Wendell, Barnard, and others, between 1898 August 17, and 1898 November 26, a comparatively short period with but few observations. Nevertheless the places derived from photographic observations made at Arequipa as long ago as 1893 December 19 (*Astronomical Journal*, Vol. xix. No. 19, 452, page 161), are not so very far from the computed places.

Knowing this when commencing this calculation in 1899 May, I did not try to improve the elements in any respect. In the time at my disposal it would have been impossible to extend the range of observations, confessedly somewhat limited, with a view

to the deduction of more accurate elements. To compute the perturbations produced by five planets during a period of 1116 (31×36) days and to obtain new elements for every thirty-sixth day is a heavy task when undertaken single-handed, nor is the work by any means concluded by the production of new orbital elements for the date of opposition. The prediction of heliocentric places at three-day intervals, and geocentric places for each noon and each transit involves much labour. For the perturbations produced by *Venus*, the Earth, *Mars*, *Jupiter*, and *Saturn*, I have employed the method of variation of constants as set forth in a paper (a perfect model for clearness and fulness of detail) by the late Astronomer Royal as an appendix to the *Nautical Almanac* for 1837, and illustrated by Woolhouse in the case of Halley's comet in the appendix for 1839.

This method does not lend itself to tabulation, and in consequence is somewhat laborious; however, it is not without its advantages. Using the method and the arrangement of formulæ employed at the *Nautical Almanac* office it was natural to adopt the data used there at the present time, in particular the following values of perturbing masses :—

log mass	*Venus*	4·39595
,,	Earth	4·48395
,,	*Mars*	3·50955
,,	*Jupiter*	6·97969
,,	*Saturn*	6·45573

In the actual calculations every effort has been made to secure accuracy, to which end the perturbations were calculated independently in duplicate by the writer and by Mr. J. Abner Sprigge of the *Nautical Almanac* office, while the heliocentric and geocentric places were carefully examined and differenced by the latter to the fourth, fifth, and sometimes even to the sixth order.

The opposition in right ascension occurs on October 30·41, and in longitude on November 11·04. The planet retrogrades in longitude from October 16 to December 15, and in right ascension from October 3 to December 5, and during the period covered by the ephemeris circles round γ *Andromedæ* at a distance of a few degrees. The greatest heliocentric latitude, 10° 50′·15 N., occurs on October 19, and the greatest geocentric latitude, 39° 38′·0 N., occurs on November 18. The planet is in perigee on December 26 at a distance 0·315.

The next opposition is in 1903 February. If this ephemeris appears to supply a need I may possibly calculate a similar ephemeris for that date, but in view of the number of astronomers who appear to be at work on this subject, I fear there is some danger of duplication.

I append the elements, &c., for mean equinox of 1900 November 1·5 :—

ε	66°	9′	4″·2
π	121	11	21·4
ν	303	33	18·5
ι	10	50	16·5
ϕ	12	52	38·3
log a	0·1637863		
n	2015″·2423		
e	0·2228644.		

Eros at Transit at Greenwich.

1900.	Apparent Right Ascension. h m s	Var. of R.A. in 1 hour of long. s	Apparent Declination. ° ′ ″	Var. of Dec. in 1 hour of long. ″	Mag.	Hor. Par. ″
Sept. 19	2 39 3·37	+1·68	N. 40 28 23·5	+57·1	10·9	13·3
20	2 39 42·32	+1·57	N. 40 51 14·3	+57·1	10·9	13·4
21	2 40 18·84	+1·47	N. 41 14 5·3	+57·1	10·9	13·6
22	2 40 52·85	+1·36	N. 41 36 56·1	+57·1	10·8	13·8
23	2 41 24·31	+1·26	N. 41 59 46·5	+57·1	10·8	13·9
24	2 41 53·09	+1·14	N. 42 22 35·7	+57·0	10·8	14·1
25	2 42 19·12	+1·02	N. 42 45 23·0	+57·0	10·7	14·3
26	2 42 42·29	+0·90	N. 43 8 8·0	+56·9	10·7	14·4
27	2 43 2·53	+0·78	N. 43 30 50·0	+56·7	10·7	14·6
28	2 43 19·75	+0·65	N. 43 53 28·0	+56·5	10·6	14·8
29	2 43 33·88	+0·52	N. 44 16 1·4	+56·3	10·6	14·9
30	2 43 44·82	+0·39	N. 44 38 29·7	+56·1	10·6	15·1
Oct. 1	2 43 52·51	+0·25	N. 45 0 52·2	+55·8	10·5	15·3
2	2 43 56·86	+0·11	N. 45 23 8·1	+55·5	10·5	15·5
3	2 43 57·79	−0·03	N. 45 45 16·6	+55·2	10·5	15·7
4	2 43 55·20	−0·18	N. 46 7 16·3	+54·8	10·4	15·9
5	2 43 49·02	−0·33	N. 46 29 6·2	+54·4	10·4	16·1
6	2 43 39·17	−0·49	N. 46 50 45·8	+53·9	10·4	16·3
7	2 43 25·52	−0·65	N. 47 12 14·0	+53·4	10·3	16·5
8	2 43 7·98	−0·81	N. 47 33 29·6	+52·9	10·3	16·7
9	2 42 46·42	−0·98	N. 47 54 31·5	+52·3	10·3	16·9
10	2 42 20·75	−1·16	N. 48 15 18·4	+51·6	10·2	17·1
11	2 41 50·92	−1·33	N. 48 35 49·2	+50·9	10·2	17·3
12	2 41 16·85	−1·51	N. 48 56 0·8	+50·1	10·2	17·5
13	2 40 38·47	−1·69	N. 49 15 51·9	+49·2	10·2	17·7

1900.	Apparent Right Ascension. h m s	Var. of R.A. in 1 hour of long. s	Apparent Declination. ° ′ ″	Var. of Decl. in 1 hour of long. ″	Mag.	Hor. Par. ″
Oct. 14	2 39 55·72	−1·87	N. 49 35 20·1	+48·2	10·2	17·9
15	2 39 8·53	−2·06	N. 49 54 24·7	+47·2	10·1	18·1
16	2 38 16·88	−2·25	N. 50 13 4·5	+46·1	10·1	18·3
17	2 37 20·70	−2·44	N. 50 31 18·4	+45·0	10·1	18·6
18	2 36 19·93	−2·63	N. 50 49 5·7	+43·9	10·1	18·8
19	2 35 14·57	−2·82	N. 51 6 24·6	+42·7	10·0	18·9
20	2 34 4·60	−3·01	N. 51 23 14·1	+41·4	10·0	19·1
21	2 32 50·12	−3·19	N. 51 39 31·3	+40·0	10·0	19·3
22	2 31 31·21	−3·38	N. 51 55 13·5	+38·5	9·9	19·5
23	2 30 8·01	−3·56	N. 52 10 17·9	+36·8	9·9	19·7
24	2 28 40·59	−3·73	N. 52 24 41·6	+35·1	9·9	20·0
25	2 27 9·11	−3·89	N. 52 38 22·6	+33·3	9·8	20·2
26	2 25 33·73	−4·05	N. 52 51 18·2	+31·4	9·8	20·4
27	2 23 54·61	−4·20	N. 53 3 27·7	+29·5	9·8	20·6
28	2 22 11·94	−4·35	N. 53 14 50·4	+27·5	9·7	20·8
29	2 20 25·94	−4·48	N. 53 25 25·6	+25·4	9·7	21·0
30	2 18 36·85	−4·60	N. 53 35 10·7	+23·3	9·7	21·2
31	2 16 44·92	−4·71	N. 53 44 4·4	+21·1	9·6	21·4
Nov. 1	2 14 50·45	−4·82	N. 53 52 5·2	+18·9	9·6	21·6
2	2 12 53·71	−4·91	N. 53 59 11·6	+16·6	9·6	21·8
3	2 10 55·03	−4·98	N. 54 5 22·7	+14·3	9·6	22·0
4	2 8 54·74	−5·04	N. 54 10 36·7	+11·9	9·6	22·2
5	2 6 53·15	−5·09	N. 54 14 53·1	+ 9·5	9·5	22·4
6	2 5 50·58	−5·12	N. 54 18 11·0	+ 7·0	9·5	22·6
7	2 2 47·41	−5·14	N. 54 20 28·8	+ 4·5	9·5	22·8
8	2 0 44·01	−5·14	N. 54 21 46·6	+ 2·0	9·5	23·0
9	1 58 40·74	−5·12	N. 54 22 3·8	− 0·6	9·4	23·2
10	1 56 38·00	−5·09	N. 54 21 19·6	− 3·1	9·4	23·4
11	1 54 36·23	−5·04	N. 54 19 33·8	− 5·7	9·4	23·6
12	1 52 35·85	−4·98	N. 54 16 46·0	− 8·3	9·3	23·8
13	1 50 37·29	−4·89	N. 54 12 56·5	−10·9	9·3	24·0
14	1 48 40·96	−4·79	N. 54 8 5·3	−13·4	9·3	24·2
15	1 46 47·26	−4·67	N. 54 2 13·0	−16·0	9·3	24·3
16	1 44 56·60	−4·54	N. 53 55 19·9	−18·5	9·3	24·5
17	1 43 9·37	−4·39	N. 53 47 27·3	−20·9	9·2	24·7
18	1 41 25·94	−4·22	N. 53 38 36·0	−23·3	9·2	24·8
19	1 39 46·68	−4·04	N. 53 28 47·0	−25·7	9·2	25·0
20	1 38 11·94	−3·85	N. 53 18 1·5	−28·0	9·2	25·2

1900.	Apparent Right Ascension. h m s	Var. of R.A. in 1 hour of long. s	Apparent Declination. ° ′ ″	Var. of Dec. in 1 hour of long. ″	Mag.	Hor. Par. ″
Nov. 21	1 36 42·06	−3·64	N. 53 6 21·1	−30·3	9·2	25·3
22	1 35 17·37	−3·42	N. 52 53 47·2	−32·5	9·2	25·4
23	1 33 58·13	−3·19	N. 52 40 21·5	−34·6	9·1	25·6
24	1 32 44·61	−2·94	N. 52 26 6·3	−36·6	9·1	25·7
25	1 31 37·01	−2·69	N. 52 11 3·2	−38·5	9·1	25·8
26	1 30 35·55	−2·43	N. 51 55 14·3	−40·4	9·1	26·0
27	1 29 40·40	−2·16	N. 51 38 41·9	−42·2	9·1	26·1
28	1 28 51·69	−1·89	N. 51 21 28·2	−43·9	9·1	26·2
29	1 28 9·55	−1·62	N. 51 3 35·0	−45·5	9·0	26·4
30	1 27 34·04	−1·34	N. 50 45 4·6	−47·0	9·0	26·5
Dec. 1	1 27 5·21	−1·06	N. 50 25 58·5	−48·4	9·0	26·6
2	1 26 43·09	−0·78	N. 50 6 18·8	−49·8	9·0	26·7
3	1 26 27·71	−0·50	N. 49 46 7·3	−51·1	9·0	26·8
4	1 26 19·02	−0·22	N. 49 25 25·8	−52·3	9·0	26·9
5	1 26 17·03	+0·06	N. 49 4 16·1	−53·4	8·9	27·0
6	1 26 21·67	+0·33	N. 48 42 40·1	−54·5	8·9	27·1
7	1 26 32·92	+0·61	N. 48 20 39·1	−55·5	8·9	27·2
8	1 26 50·73	+0·88	N. 47 58 14·9	−56·5	8·9	27·3
9	1 27 15·03	+1·15	N. 47 35 29·1	−57·3	8·9	27·3
10	1 27 45·79	+1·41	N. 47 12 23·0	−58·1	8·9	27·4
11	1 28 22·94	+1·68	N. 46 48 58·1	−58·9	8·9	27·4
12	1 29 6·42	+1·94	N. 46 25 16·1	−59·6	8·9	27·5
13	1 29 56·16	+2·20	N. 46 1 18·0	−60·2	8·9	27·5
14	1 30 52·07	+2·46	N. 45 37 5·2	−60·8	8·9	27·6
15	1 31 54·08	+2·71	N. 45 12 38·7	−61·4	8·9	27·6
16	1 33 2·11	+2·96	N. 44 47 59·5	−61·9	8·9	27·7
17	1 34 16·04	+3·20	N. 44 23 9·4	−62·3	8·8	27·7
18	1 35 35·77	+3·44	N. 43 58 9·9	−62·6	8·8	27·8
19	1 37 1·18	+3·68	N. 43 33 2·4	−63·0	8·8	27·8
20	1 38 32·18	+3·91	N. 43 7 47·5	−63·3	8·8	27·8
21	1 40 8·62	+4·13	N. 42 42 25·9	−63·6	8·8	27·8
22	1 41 50·41	+4·35	N. 42 16 57·9	−63·8	8·8	27·8
23	1 43 37·46	+4·57	N. 41 51 25·7	−63·9	8·8	27·9
24	1 45 29·68	+4·78	N. 41 25 49·7	−64·0	8·8	27·9
25	1 47 26·93	+4·99	N. 41 0 11·7	−64·1	8·8	27·9
26	1 49 29·11	+5·19	N. 40 34 31·4	−64·2	8·8	27·9

Note on the accuracy of the Star Charts published by the French Observatories as reproductions of their Plates for the Astrographic Chart. By H. H. Turner, M.A., F.R.S., Savilian Professor.

1. The French observatories which are taking a share in the International Astrographic Chart (Paris, Algiers, Bordeaux, Toulouse)* have already published a number of large paper sheets, reproducing by heliogravure the long-exposure plates on a scale of 2^{mm} to $1'$ (twice that of the original negatives). These reproductions are very beautiful, but apparently somewhat expensive. From figures mentioned at the meeting of the Permanent Committee last July, it would seem that it would cost each observatory about 10,000*l.* to reproduce their plates in this way. Now some of the participating observatories will not find it easy to obtain a sum of this kind for the work; and it becomes important to know what we may expect in return, and especially what is the order of accuracy of these maps. We have not been hitherto accustomed to associate any very great accuracy with paper star maps. They represent well enough the general configurations of the stars, but have not been intended for exact measurement. The charts of *Argelander* and *Chacornac*, for instance, do not always give the places correctly to $1'$; a case has been quoted (see *Mem. R. A. S.*, vol. lii., p. 184) where one of the latter is in error for $3'$ or $4'$ over a sensible area. No such errors are likely to occur in photographic reproductions, but very little has been published to show what accuracy can be obtained from paper prints. Five years ago I showed that a very considerable accuracy was attainable in contact prints (*Monthly Notices*, vol. lvi., p. 26); and in this paper it was stated that the images on the prints, especially of the réseau-lines, were rather diffuse, so that better results might be expected when attention was paid to securing better images.

2. No opportunity for continuing the investigation has presented itself until recently, when a portion of one of the beautiful reproductions of the Paris Observatory was examined. These measures are not sufficiently extended to settle the question of accuracy completely, but may serve to draw attention to the need for settling it. They seem to indicate that *we can get star-places from these paper charts at least as good as those obtained with meridian instruments.* On finding this result, I wrote to M. Loewy and M. Trépied, suggesting that a much more complete investigation could be made by comparing measures of these paper reproductions with measures of the original negatives; and a courteous reply was at once received, saying that the investigation should be undertaken. At the same time a wish was

* We have also recently received two sheets of the same kind from the San Fernando Observatory.

expressed that these measures should be published. They have the incompleteness and roughness of a preliminary investigation, but the necessity of attending to the Opposition of *Eros* prevents the thorough revision that might otherwise be given to them; and they will at least serve the purpose, as remarked above, of drawing attention to an important matter.

3. The whole of the work was done by Mr. F. C. H. Carpenter, Assistant at the Durham Observatory. Mr. Carpenter was for some years at the University Observatory, Oxford, which he left for his appointment at Durham, and during a recent holiday visit to Oxford he requested permission to measure and reduce a few plates as in the old days (a request which was naturally gratifying, as showing that such work is not irksome), and I suggested that, instead of measuring one of the regular plates of our zone, he should make some measures on one of the Paris charts in zone $+24°$, which overlaps our zone $+25°$, and compare them with measures on an Oxford plate, in order to test the accuracy of the paper charts. He willingly assented, and what follows is the result of his work.

4. The Paris chart selected had centre at $+24°$, $20^h\ 40^m$, and the Oxford plate $+25°$, $20^h\ 44^m$. The quarter-plate of the paper chart overlapping the Oxford plate was carefully cut out along the bounding réseau-lines, and placed between two pieces of plate-glass. Being on twice the linear scale, the quarter plate was about the size of one of the ordinary plates, and could be fitted into one of the regular measuring machines; but, of course, the squares of the réseau on it were just twice as broad as those on an ordinary plate. Hence the cross-scales in the eye-piece of the measuring machine (for description see *Monthly Notices*, vol. lv., p. 102), instead of each cutting *two* réseau-lines, could only each cut *one*. In the ordinary way we get with this machine two readings for each coordinate, say x_1 x_2 and y_1 y_2; such that the differences $x_1 - x_2$ and $y_1 - y_2$ are small, and indicate the correction for "runs" (*i.e.* want of equality between 100 div. of the scales and one réseau interval). With the paper chart we get either x_1 or x_2, but not both; and thus have no correction for runs, which is important in measuring a paper reproduction. Fortunately the squares were generally just a little smaller than the total length of the scale; so that the corrections for runs, although not obtainable incidentally in measuring the star, could be got from a separate operation by setting the four ends of the two scales just on réseau-lines. The corrections thus obtained were assumed to apply to the whole square, and the *single* measures of each coordinate were then corrected for runs. But it will be obvious that here we have sources of inaccuracy due to the method of measurement, and not to the charts themselves. Better methods of measurement could readily be devised; but in this preliminary investigation this method, ready to hand, was considered sufficient.

5. As the paper chart, with exposures of 30^m, contained more

stars than the Oxford plate with exposures 6^m and 3^m, it was advisable to identify the stars to be measured on the former. From a few selected stars provisional linear formulæ were found connecting coordinates on one plate with those on the other; and the Oxford measures were then reduced, by use of these formulæ, to approximate accordance with the paper chart.

6. Measures were then made on the chart by setting the cross of the scale by estimation *in the centre of the triangle formed by the three images.* Here again is a probable inaccuracy, due merely to the method of measurement. By selecting one of the images, or better still, by measuring all three, the accuracy of the present measures could almost certainly be improved.

7. *Ninety* stars were then measured and compared. From *twenty* of these, four equations were formed in the ordinary way to find the exact linear formulæ connecting the two plates. The small corrections of the second order, due to the difference of centres of the plates, were at first neglected as probably representing too high an order of accuracy for this investigation; but were afterwards applied when it was found how accurate the measures were.

8. Applying the linear corrections found to the differences, the ninety residuals were found to be grouped as follows :—

Residual.		No. of cases.		Residual.		No. of cases.	
	″	In x.	In y.		″	In x.	In y.
+8 =	+2·4	1	0	0	0·0	10	17
+7 =	+2·1	0	1	−1 =	−0·3	19	10
+6 =	+1·8	0	2	−2 =	−0·6	12	9
+5 =	+1·5	3	5	−3 =	−0·9	11	5
+4 =	+1·2	5	4	−4 =	−1·2	4	4
+3 =	+0·9	5	10	−5 =	−1·5	4	3
+2 =	+0·6	4	12	−6 =	−1·8	0	1
+1 =	+0·3	12	8	−7 =	−2·1	0	1

Allowing for the two sources of inaccuracy above indicated, these differences show that the measures made on the paper chart are very nearly, if not quite, as good as the measures made on our Catalogue plates. The probable error of a single measure on the paper chart is not much greater than 0″·3, though in view of the provisional nature of the measures, it does not seem worth while to give an exact value to it.

It should further be remarked that the stars measured were of all sizes. The larger stars do not show the three images separated, but only a triangular patch; the charts are not meant to give the places of these with great accuracy.

9. In conclusion I would venture to add one remark with regard to the construction of these charts. If these indications of their accuracy are confirmed and extended by measures made under more favourable conditions at the French observatories,

may it not be well to reconsider the practice of adding any finishing touches by hand? I gathered at the meeting of the Committee last July that a few touches are occasionally necessary—to insert stars accidentally omitted, &c. It seems improbable that these can be made with the accuracy which characterises the rest of the chart, and it might be well at least to indicate clearly in the margin where any artificial additions have been made. But I may have misunderstood what is done.

Observations of Phenomena of Jupiter's Satellites at Windsor, New South Wales, in the Years 1898 *and* 1899. By John Tebbutt.

Day of Obs. 1898.	Satellite.	Phenomenon.	Phase.	Mag. Power.	G.M.T. of Observation. h m s	Mean Time of *Naut. Alm.* h m s
Mar. 29	I.	Tr. Egr.	Int. contact	168	23 7 43	
29	I.	„	Bisection	„	23 9 13	23 14
29	I.	„	Ext. contact	„	23 13 37	
30	II.	„	Int. contact	„	22 5 54	
30	II.	„	Bisection	„	22 8 9	22 12
30	II.	„	Ext. contact	„	22 12 18	
30	III.	Tr. Ingr.	Ext. contact	„	23 11 18	
30	III.	„	Bisection	„	23 18 2	23 17
30	III.	„	Int. contact	„	23 23 11	
Apr. 6	Shd. I.	Transit	On cent. merid.	74	0 7 0	
6	II.	Tr. Ingr.	Ext. contact	168	21 54 27	
6	II.	„	Bisection	„	21 57 11	21 56
6	II.	„	Int. contact	„	21 59 46	
6	I.	Ecl. R.	First seen	74	22 23 59	22 24 13
13	I.	Occ. D.	First contact	168	21 37 37	
13	I.	„	Bisection	„	21 39 17	21 38
13	I.	„	Last seen	„	21 40 56	
14	II.	Tr. Ingr.	Ext. contact	„	0 8 57	
14	II.	„	Bisection	„	0 11 21	0 9
14	II.	„	Int. contact	„	0 14 41	
14	I.	Ecl. R.	First seen	74	0 17 56	0 18 10
14	I.	„	Full brightness	„	0 21 30	
18	III.	„	First seen	„	0 18 42	0 19 19
18	III.	„	Full brightness	„	0 29 0	
May 30	I.	Tr. Egr.	Ext. contact	168	20 55 3	20 54
30	III.	Ecl. D.	Began to fade	74	21 37 6	
30	III.	„	Last seen	„	21 47 28	21 42 0

Day of Obs. 1899.	Satellite.	Phenomenon.	Phase.	Mag. Power.	G.M.T. of Observation. h m s	Mean Time of *Naut. Alm.* h m s
Apr. 21	III.	Tr. Ingr.	Ext. contact	168	22 53 42	
21	III.	,,	Bisection	,,	23 2 35	23 1
21	III.	,,	Int. contact	,,	23 11 29	
21	III.	Tr. Egr.	Int. contact	,,	23 48 32	
21	III.	,,	Bisection	,,	23 57 41	24 10
22	III.	,,	Ext. contact	,,	0 7 54	
23	II.	Ecl. D.	Began to fade	132	23 29 7	
23	II.	,,	Last seen	,,	23 32 17	23 32 10
May 2	I.	Occ. D.	First contact	230	23 3 4	
2	I.	,,	Bisection	,,	23 4 48	23 4
2	I.	,,	Last seen	,,	23 7 8	
3	I.	Tr. Egr.	Int. contact	,,	22 21 54	
3	I.	,,	Bisection	,,	22 23 59	22 26
3	I.	,,	Ext. contact	,,	22 26 58	
18	I.	Occ. D.	First contact	168	20 56 35	
18	I.	,,	Bisection	,,	20 59 25	20 59
18	I.	,,	Last seen	,,	21 1 24	
18	II.	Ecl. R.	First seen	74	22 53 35	22 55 44
18	II.	,,	Full brightness	,,	22 57 20	
18	I.	,,	First seen	,,	23 40 41	23 41 5
18	I.	,,	Full brightness	,,	23 43 47	
19	I.	Tr. Egr.	Int. contact	168	20 17 25	
19	I.	,,	Bisection	,,	20 20 20	20 23
19	I.	,,	Ext. contact	,,	20 23 39	
25	II.	Occ. D.	First contact	,,	21 48 30	
25	II.	,,	Bisection	,,	21 51 14	21 52
25	II.	,,	Last seen	,,	21 56 49	
25	I.	,,	First contact	,,	22 43 26	
25	I.	,,	Bisection	,,	22 45 30	22 44
25	I.	,,	Last seen	,,	22 47 5	
June 9	I.	Tr. Ingr.	Ext. contact	,,	23 29 28	
9	I.	,,	Bisection	,,	23 31 23	23 33
9	I.	,,	Int. contact	,,	23 33 47	
10	I.	Occ. D.	First contact	74	20 40 30	
10	I.	,,	Bisection	,,	20 44 10	20 45
10	I.	,,	Last seen	,,	20 46 34	
10	II.	Tr. Ingr.	Ext. contact	,,	21 0 37	
10	II.	,,	Bisection	,,	21 5 26	21 4

Day of Obs.	Satellite.	Phenomenon.	Phase.	Mag. Power.	G.M.T. of Observation.	Mean Time of *Naut. Alm.*
1899.					h m s	h m s
June 10	II.	Tr. Ingr.	Int. contact	74	21 9 31	
10	III.	,,	Bisection	,,	22 20 34	22 21
10	III.	,,	Int. contact	,,	22 26 53	
10	II.	Tr. Egr.	Int. contact	,,	23 21 49	
10	II.	,,	Bisection	,,	23 25 18	23 23
10	II.	,,	Ext. contact	,,	23 30 47	
10	I.	Ecl. R.	First seen	,,	23 52 10	23 52 26
10	I.	,,	Full brightness	,,	23 54 43	
10	III.	Tr. Egr.	Int. contact	,,	23 55 53	
11	III.	,,	Bisection	,,	0 3 12	0 6
11	III.	,,	Ext. contact	,,	0 11 50	
July 26	I.	Occ. D.	First contact	70	20 49 22	
26	I.	,,	Bisection	,,	20 51 31	20 51
26	I.	,,	Last seen	,,	20 53 6	
27	I.	Ecl. R.	First seen	,,	0 17 28	0 17 27
27	I.	,,	Full brightness	,,	0 19 22	
28	II.	Occ. R.	Last contact		22 38 22	22 38
28	II.	Ecl. D.	Began to fade		22 49 20	
28	II.	,,	Last seen		22 54 24	22 53 16
Sept. 19	I.	Ecl. R.	First seen	70	21 6 46	21 6 59
19	I.	,,	Full brightness	,,	21 10 4	

Notes.

1898.

March 29.—Definition only occasionally good.

March 30.—Definition fairly good for Satellite II., and good for Satellite III.

April 6.—Transit of shadow estimated. Definition of II. pretty satisfactory; but the eclipse of I. was observed through cloud with full moon present.

April 13 and 14.—Sky beautifully clear; steadiness and definition pretty satisfactory throughout.

April 18.—Sky beautifully clear; images steady and well defined.

May 30.—Definition excellent and observation of contact unusually good. Sky clear and definition good at the eclipse. Satellite suspected five or six seconds later.

1899.

April 21 and 22.—Satellite visible throughout the transit as a bright disc. Definition was generally pretty good and occasionally very good. It was extremely difficult to fix the times of the phases in consequence of the oblique path of the satellite across the planet's limb.

April 23.—Definition pretty good, but Moon near her opposition and not far from planet.

May 2.—Definition pretty good, but last phase difficult to observe.

May 3.—Images tremulous and definition bad.

1899.
May 18.—Definition pretty good throughout. The first phase of the eclipse of II. was observed rather late. The eclipse of I. was well observed. Sky beautifully clear, but Moon present.
May 19.—Definition bad and images tremulous.
May 25.—Definition pretty good.
June 9.—Definition bad and images tremulous.
June 10 and 11.—Definition bad and images tremulous; a higher power could not be employed.
July 26.—Definition good and images steady.
July 27.—Observation rather late, the satellite being rather conspicuous. The recorded minute was doubtful.
July 28.—Steadiness and definition satisfactory, but impossible to observe the final disappearance within five seconds. Clouds prevented an observation of the reappearance. This is, I believe, the third time a disappearance of the second satellite has been observed at Windsor after the planet's opposition, and the systematic observations taken here extend over a period of thirty-five years.
September 19.—Sky clear and definition pretty good, but Moon just risen.

An occulting bar was not employed in the observations. The times given are the Windsor mean times of observation diminished by 10 hrs. 3 mins. 20·5 secs., and entered to the nearest second. The observations of full brightness in the eclipses are at the best only rough approximations. In determining these times the increasing light of the satellite was repeatedly compared with the other visible satellites. The observations of July 28 were made with the $4\frac{1}{2}$-inch telescope, and all the others with the 8-inch instrument.

Observatory, Peninsula, Windsor, N. S. Wales:
1900 *August* 25.

Erratum in Monthly Notices, vol. lx.

P. 570, line 9 from top, *for* Approx. *read* Apparent.

LIST OF WORKS
PRESENTED TO THE SOCIETY,
AND OF
WORKS PURCHASED WITH THE TURNOR AND HORROX FUND,
JUNE 1899 TO JUNE 1900.

An asterisk (*) indicates that the work is an excerpt.

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